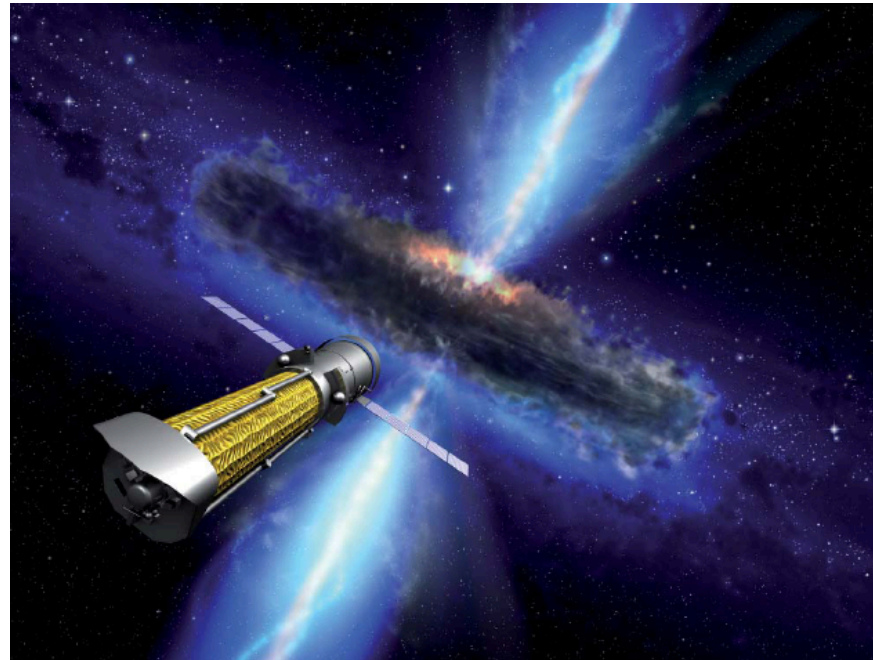




How does IXO fit in the big picture?



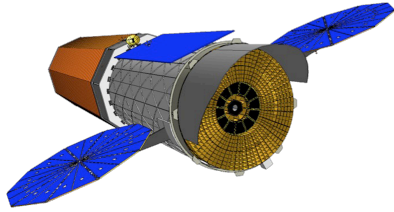
Xavier Barcons

Instituto de Física de Cantabria (CSIC-UC),
Santander, Spain

IXO, Rome, March
2011

IXO in the big picture





Topics

- IXO science goals in context
 - * Are those central to mainstream Astrophysics?
- Synergies with other large facilities
 - * Mutual benefits for both IXO and other facilities

IXO science goals:

- **Co-evolution of galaxies and their SMBH**

- * The first SMBH.
- * Obscured growth of SMBH
- * Feedback in galaxies and clusters

- **Large-scale structure and the creation of chemical elements**

- * Are the missing baryons in the WHIM?
- * Cluster physics and evolution
- * Cosmology with clusters
- * The creation of chemical elements

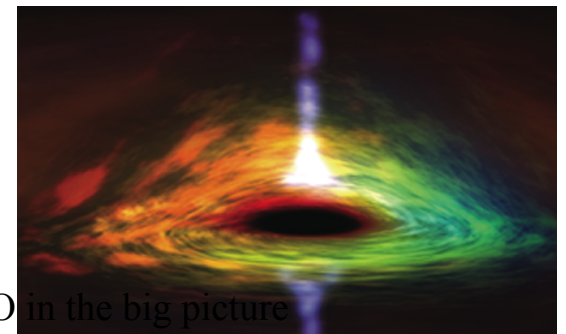
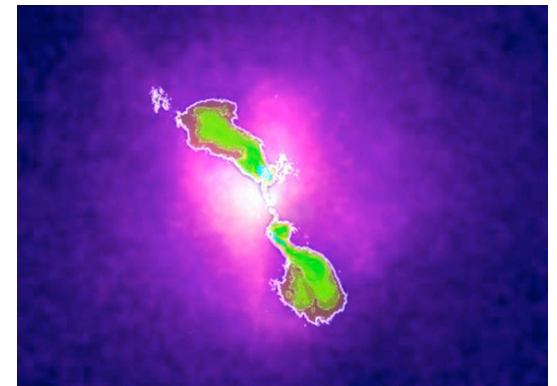
- **Matter under extreme conditions**

- * Physics of strong gravity
- * Neutron Star Equation of State

- **Life cycles of matter and energy:**

- * Physics of SNe and SNR
- * The ISM in our Galaxy, the GC
- * Stars and planets

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IXO in the big picture

The question

- Are the IXO science goals part of mainstream Astronomy?

or

- Are IXO science goals mostly relevant to X-ray astronomers, but rather marginal to mainstream Astronomy?

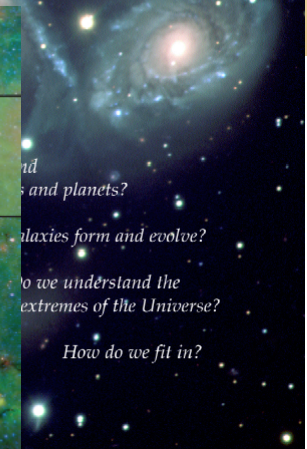
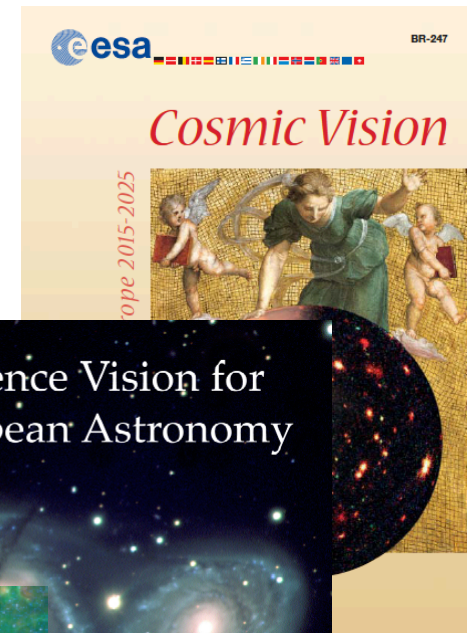
Astronomy roadmaps

- Europe:

- * ESA Cosmic Vision 2015-2025 science goals
- * ASTRONET Science Vision

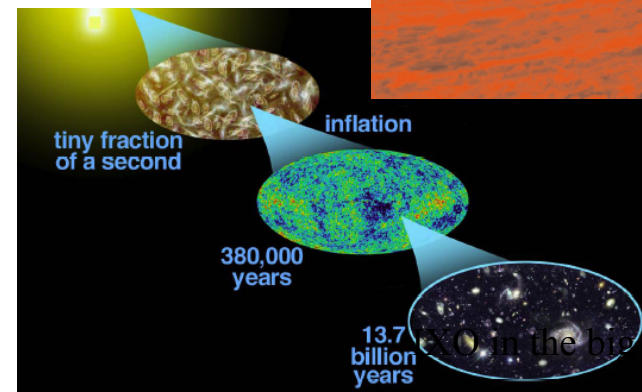
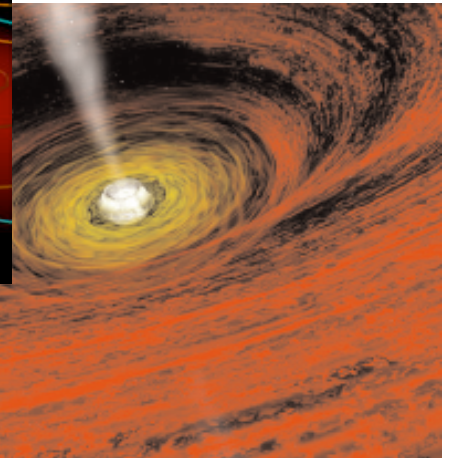
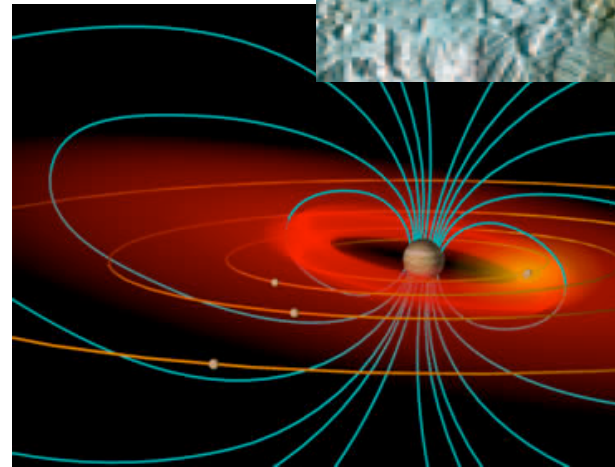
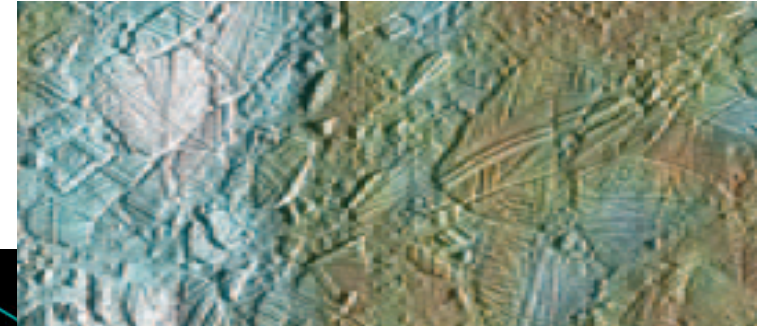
- USA:

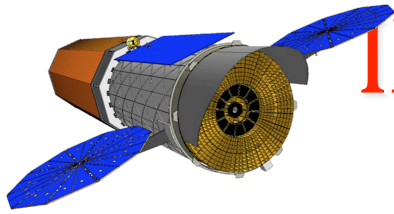
- * ASTRO 2010 Decadal Survey



Cosmic Vision 2015-2025

1. What are the conditions for planet formation and the emergence of life?
2. How does the Solar System work?
3. What are the fundamental physical laws of the Universe
4. How did the Universe originate and what is it made of?





IXO vs Cosmic Vision

What are the fundamental physical laws of the Universe?

- * Explore the limits of contemporary physics
- * The gravitational wave Universe
- * **Matter under extreme conditions**

How did the Universe originate and what is it made of?

- * The Early Universe
- * **The Universe taking shape**
- * **The evolving violent Universe**

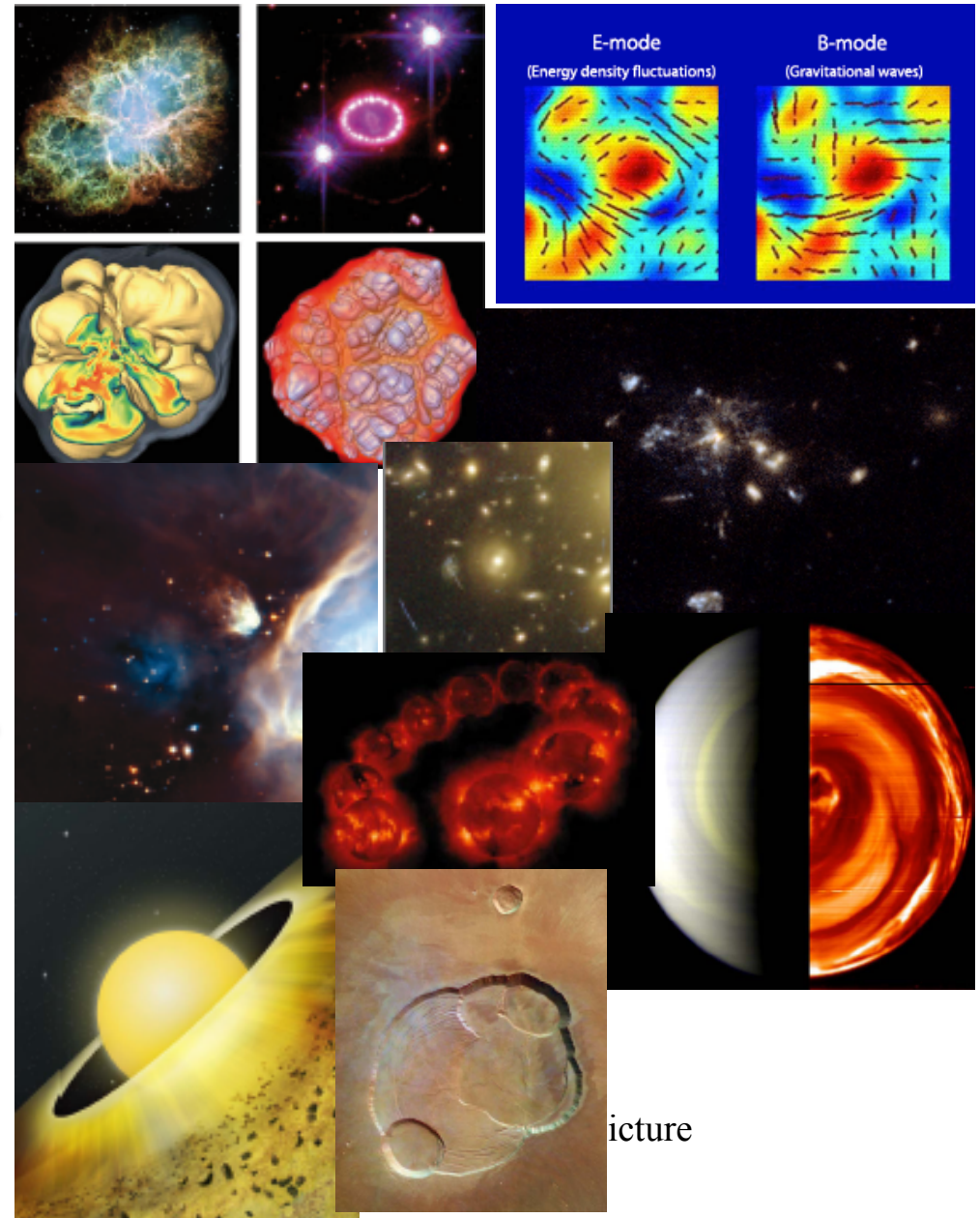
IXO needed

IXO useful

Astronet Science Vision

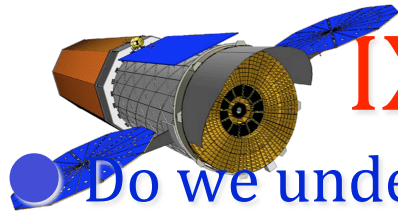
<http://www.astronet-eu.org>

- What is the origin and evolution of stars and planets?
- How do galaxies form and evolve?
- Do we understand the extremes of the Universe?
- How do we fit in?



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picture



IXO in the Astronet Roadmap

● Do we understand the extremes of the Universe (7)

- * Towards a coherent picture of DM and DE
- * **Test General Relativity around black holes**
- * **Astrophysics of compact objects, SNe and GRBs**

● How did galaxies form and evolve (7)

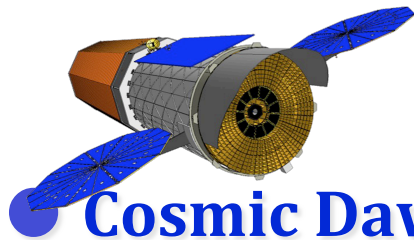
- * **Detect the first stars, black holes and galaxies**
- * **Measure the WHIM metal content and find missing baryons**
- * **Mesure the buid-up of gas, dust in galaxies and the connection between black hole and galaxy growth**

● How do stars and planets form (6)

- * Initial conditions for SF and development into single or multiple systems
- * **Life cycle between ISM and stars through stellar evolution**

ASTRO 2010: New worlds, New Horizons in Astronomy & astrophysics

- **Cosmic Dawn:** Searching for the first stars, galaxies and black holes
 - * Go back to reionisation epoch
 - * Cosmic paleontology: stars with lowest abundances
- **New worlds:** Seeking nearby habitable planets
 - * Understand distribution of different planet types
 - * Lay down foundations to study nearby Earth-like planets
- **Physics of the Universe:** Understand scientific principles
 - * Determine properties of Dark Energy
 - * Characterize Dark Matter
 - * Characterze Inflation
 - * Test General Relativity through BHs and mergers



IXO and ASTRO 2010

- **Cosmic Dawn:** Searching for the first stars, galaxies and black holes
 - * **Go back to reionisation epoch**
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 - * **Test General Relativity through BHs and mergers**

Which of IXO science goals are high priorities in the roadmaps?

Theme/question	Cosmic Vision	Astronet	Astro2010
----------------	---------------	----------	-----------

Co-evolution of galaxies and their supermassive black holes (SMBH)

The first SMBH			
Obscured growth of SMBH			
Cosmic feedback from SMBH			

Large-scale structure and the creation of chemical elements

Missing baryons and the Intergalactic Medium			
Cluster Physics and Evolution			
Galaxy cluster cosmology			
Chemical evolution along cosmic time			

Matter under extreme conditions

Strong gravity and accretion physics			
Neutron Star Equation of State			

Bottom line

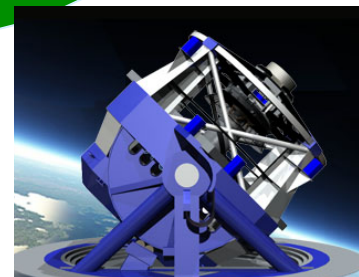
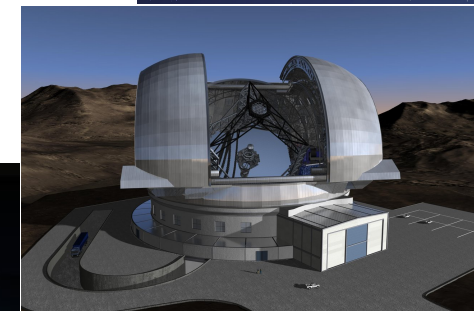
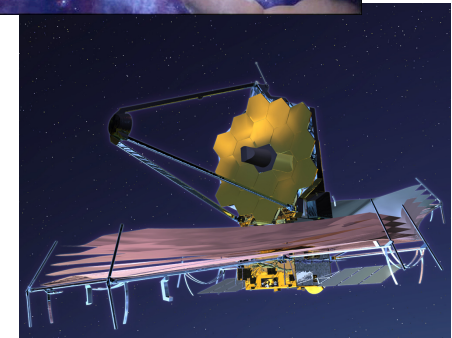
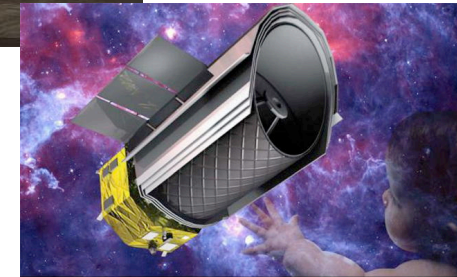
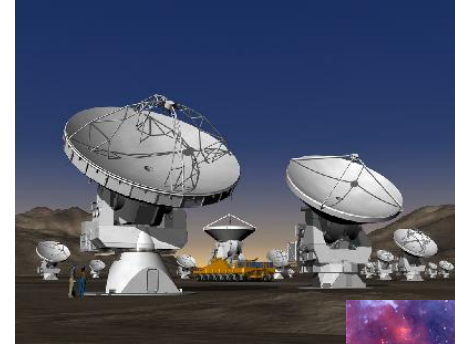
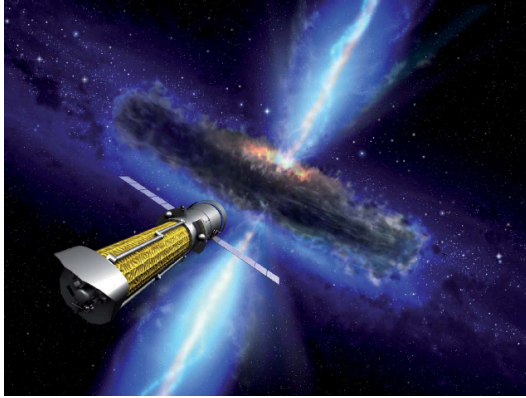
IXO science goals that appear very central to mainstream Astrophysics:

- **First SMBH and galaxies after dark ages**
- **Connection between SMBH and galaxy growth**
- **GR phenomena around black holes and accretion physics**
- **Dark Matter and Dark Energy**
- Missing baryons and the WHIM
- Cluster physics and evolution
- Chemical evolution
- Neutron Star Equation of state

But, for mainstream Astrophysics

- Growing SMBH are not interesting, rather a nuisance masking star formation
- Feedback is “termination of star formation”, not larger-scale effects
- Precision cosmology probes are CMB, BAO, lensing and only marginally clusters

Synergies

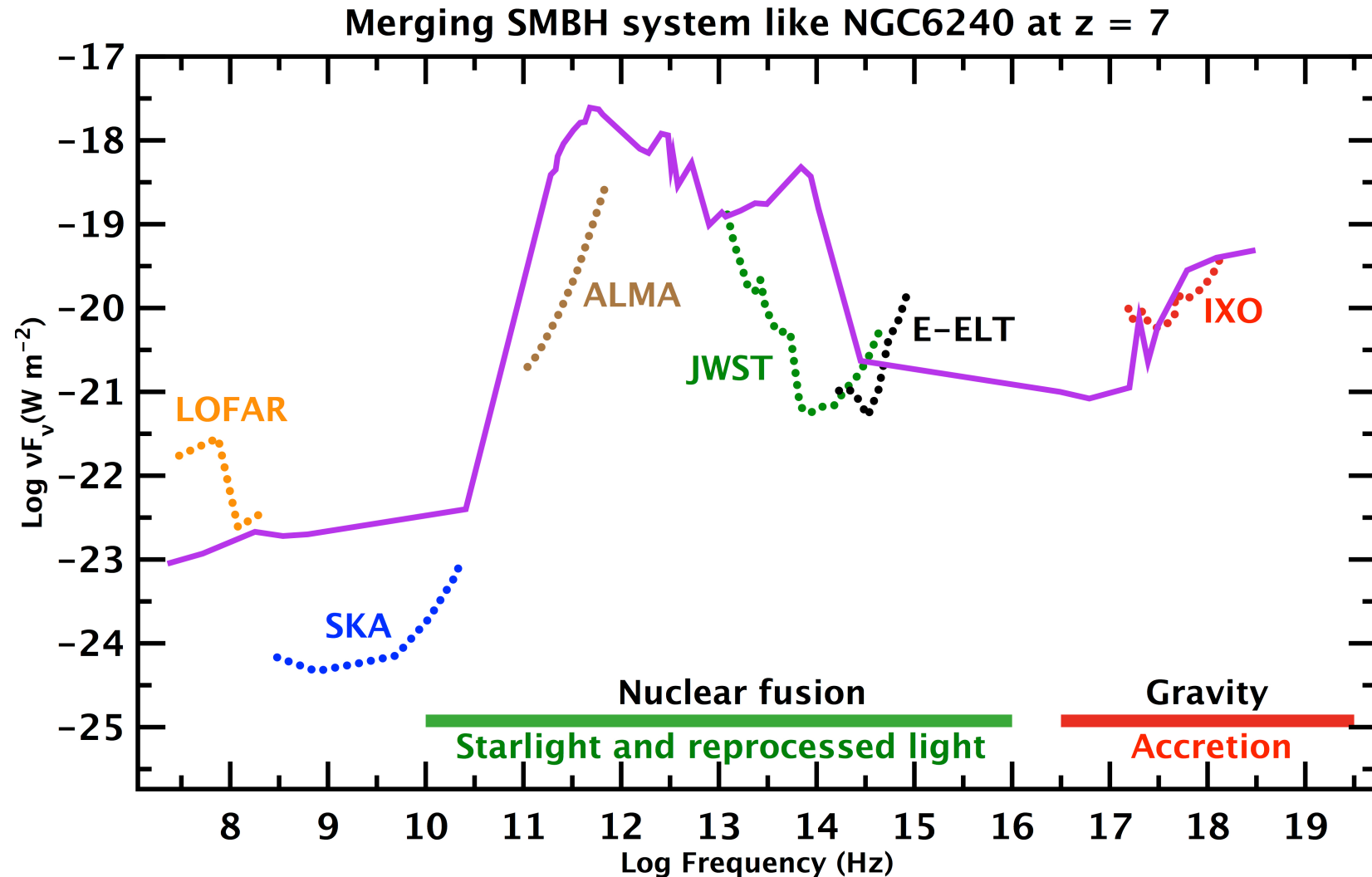


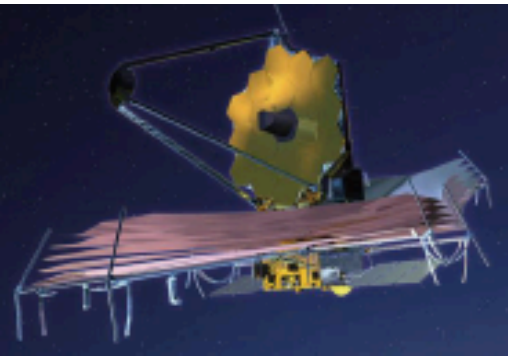
Synergy: Two or more agents working together to produce a result not obtainable by any of the agents independently.
(Source: wikipedia)

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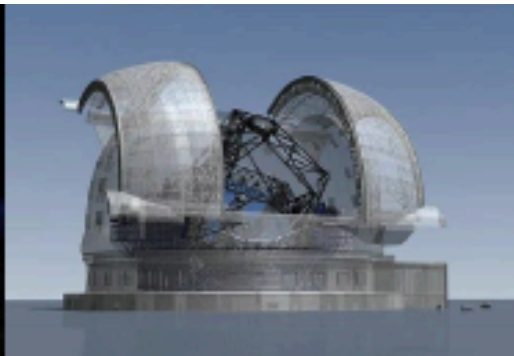
IXO in the big picture

IXO in the context of the large observatories to come





JWST



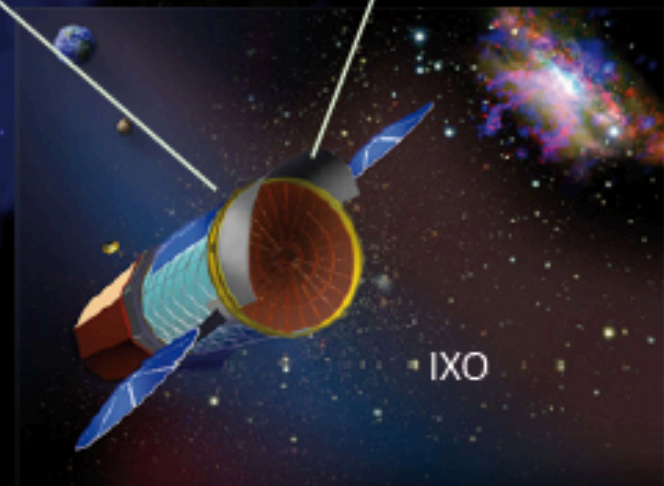
E-ELT



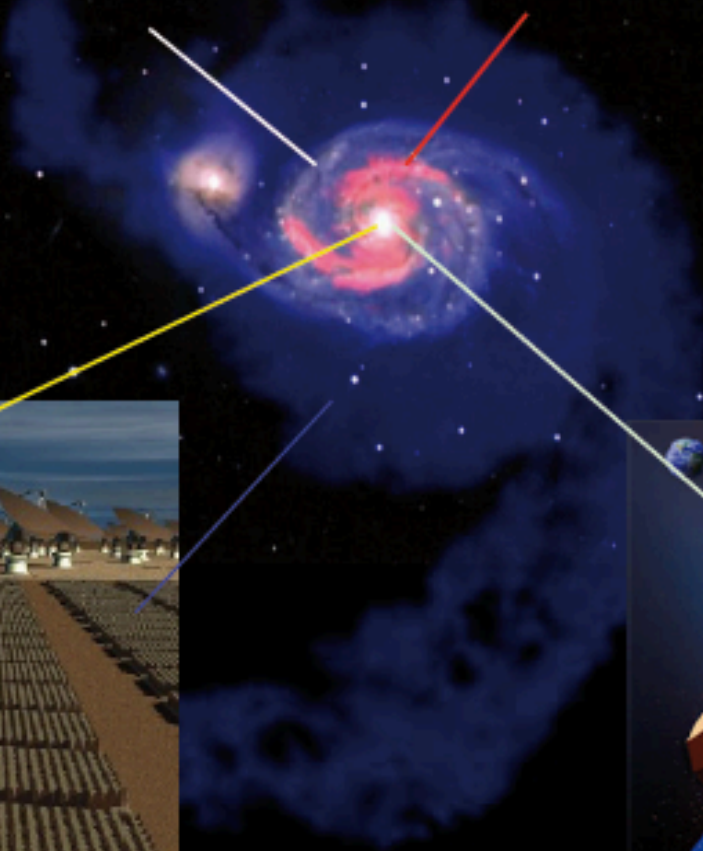
ALMA

Credit: S. Rawlings
IXO Science meeting
Paris 2010

SKA

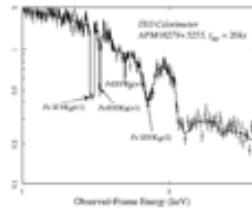


IXO

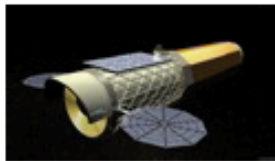


Witnessing coevolution at modest z

IXO-ELT-Euclid synergy flow Galaxy-BH co-evolution



IXO



High R spectroscopy

- Kinematics of hot gas from spectral absorption features
- Feedback mechanisms at $z \sim 1-3$
- BH accretion rates

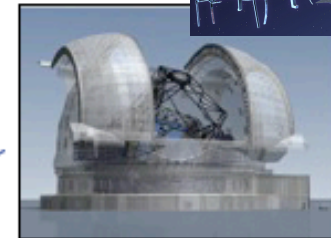
Euclid



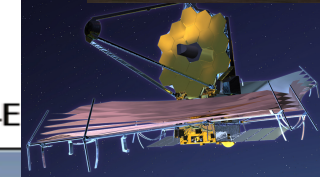
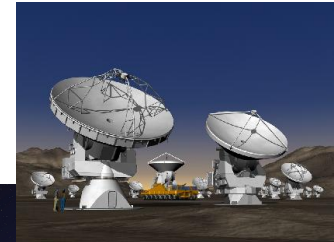
Vast reservoir of AGN
for IXO, ELT follow-up

$M_{\text{BH}}-\sigma-(M_*, L)$ relation,
evolution, scatter

$M_{\text{BH}}, \dot{M}_{\text{BH}}, M_*, \sigma$
from $z \sim 0$ to 3



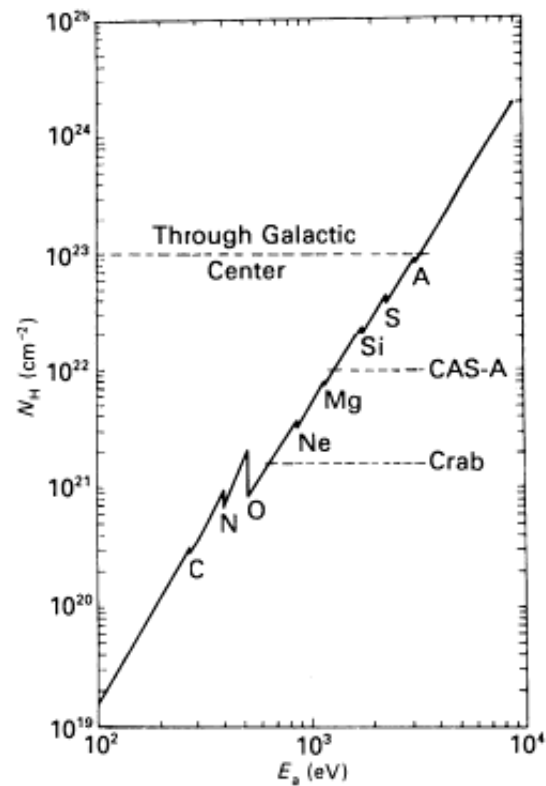
- Direct dynamical BH masses by resolving the Sol out to $z \sim 0.5$
- "AGN-free" imaging of hosts with IFUs
- "Virial" BH masses in NIR of IXO selected AGN over a broad range of redshifts, L_x and obscuration



Credit: P. Rosati,
IXO Paris meeting

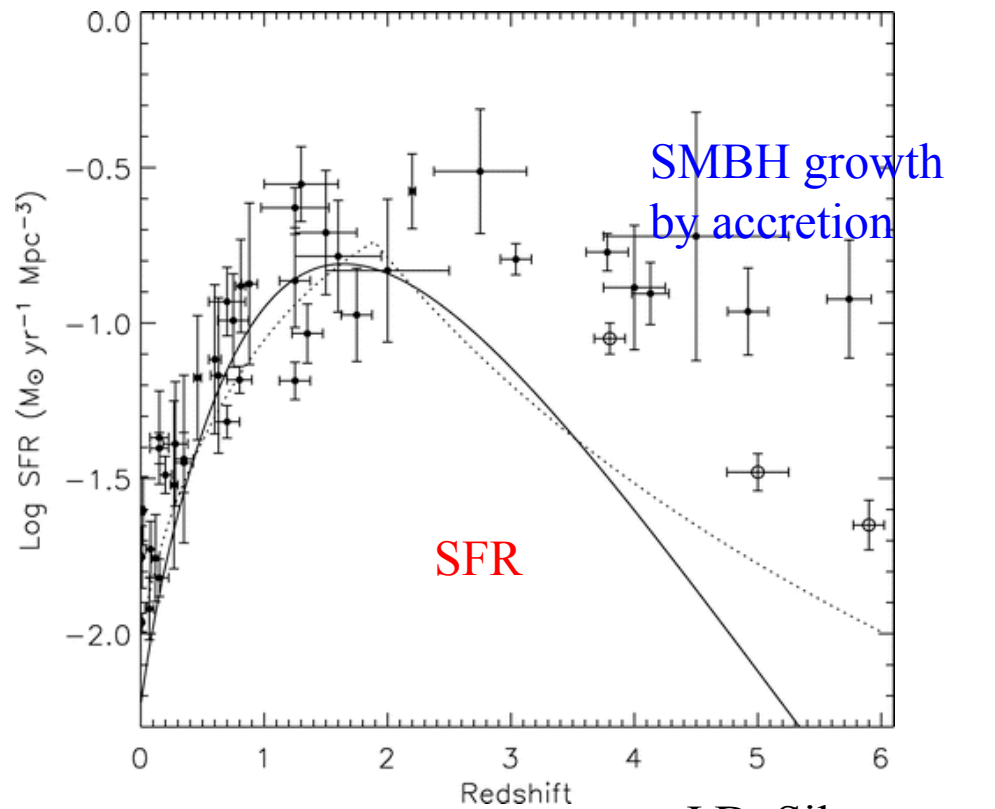
Obscured SMBH growth and star formation

SPICA: SFR @ $z \sim 2$



← Far-IR
 ← Mid-IR
 ← Near-IR
 ← Optical

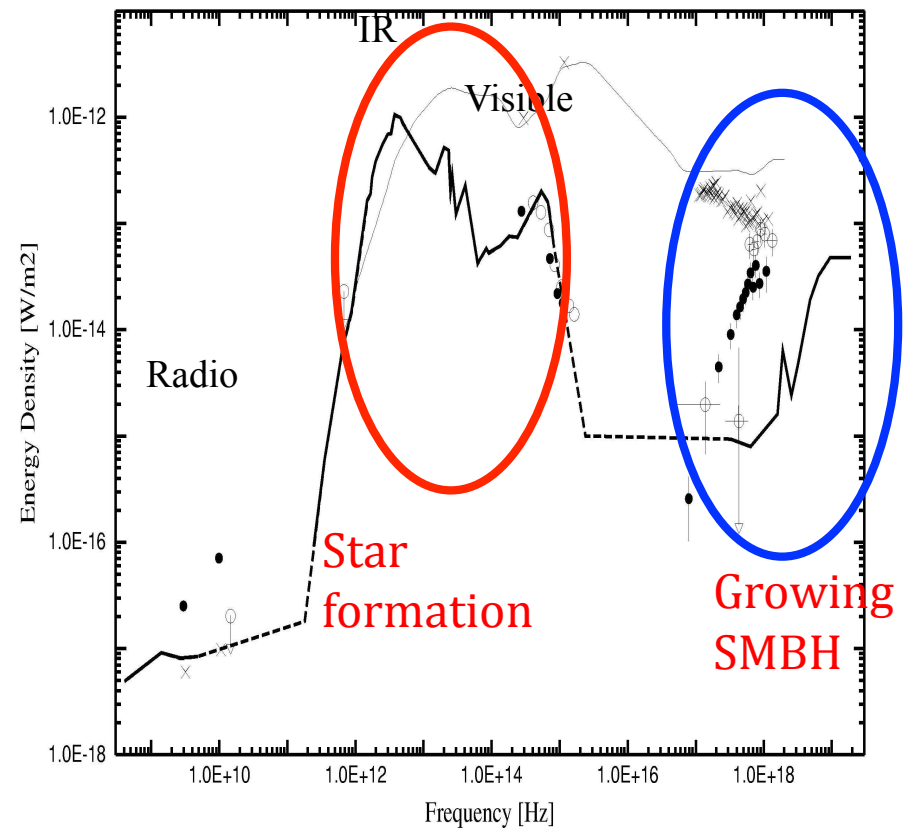
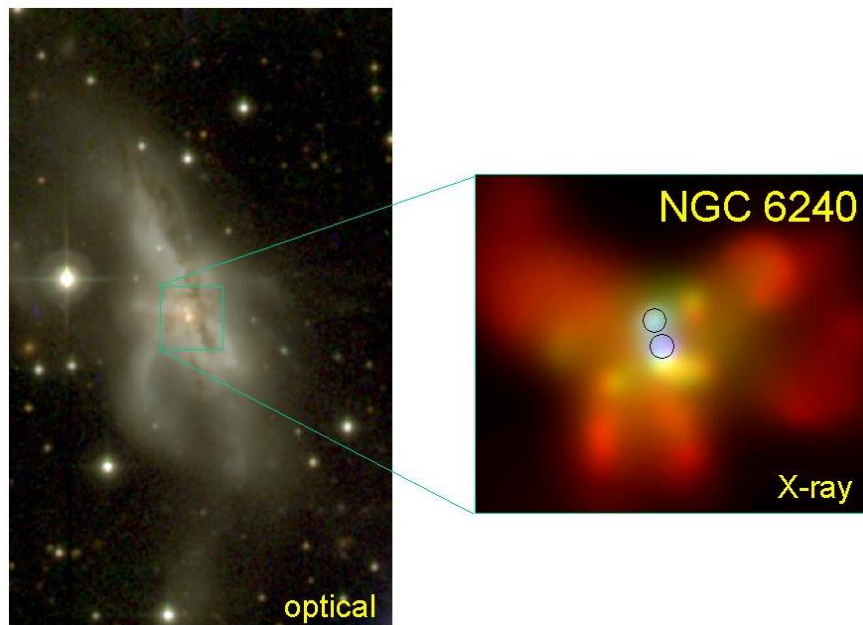
SMBH growth vs SFR history



J.D. Silverman

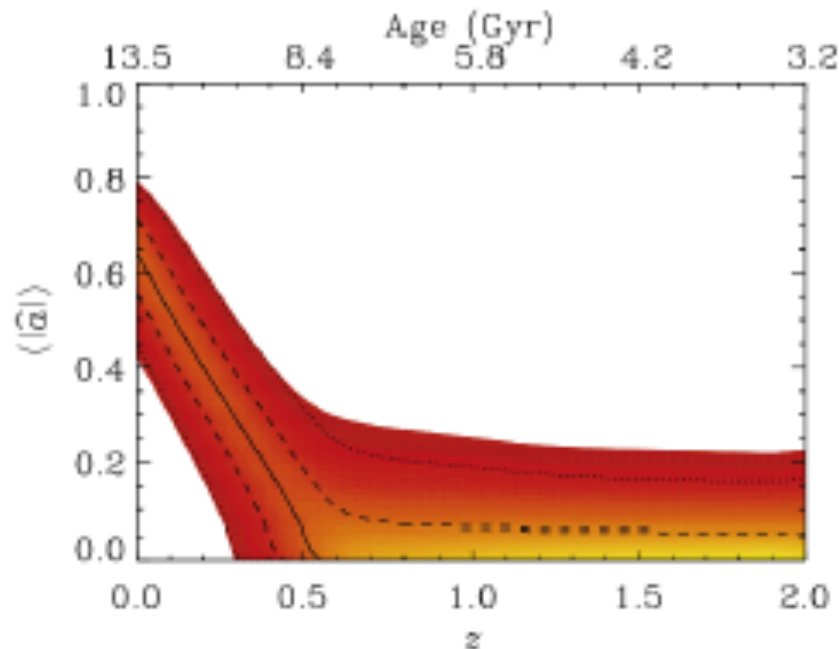
The obscured population at high- z

X-ray/optical/IR views of NGC620



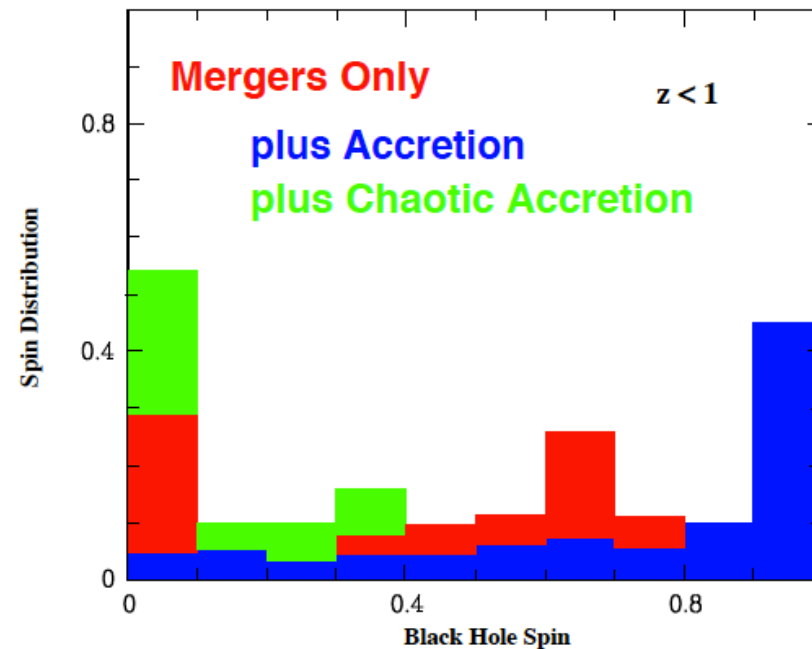
SMBH spin as a tracer of galaxy evolution

SKA (from jets)



M-Sansigre & Rawlings 2010

IXO (from Fe line profile)



Berti & Volonteri 2008

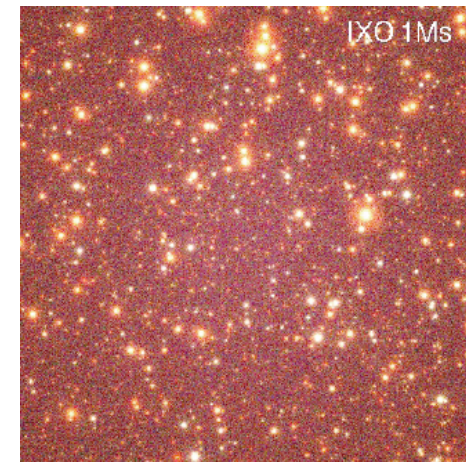
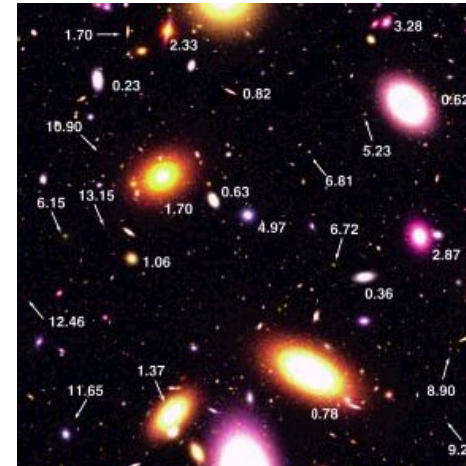
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IXO in the big picture

First light & deep surveys

E-ELT/JWST will
see starlight of
first galaxies up
to re-ionisation

IXO will find in
which galaxies
there is an
accreting SMBH
out to $z > 7$.

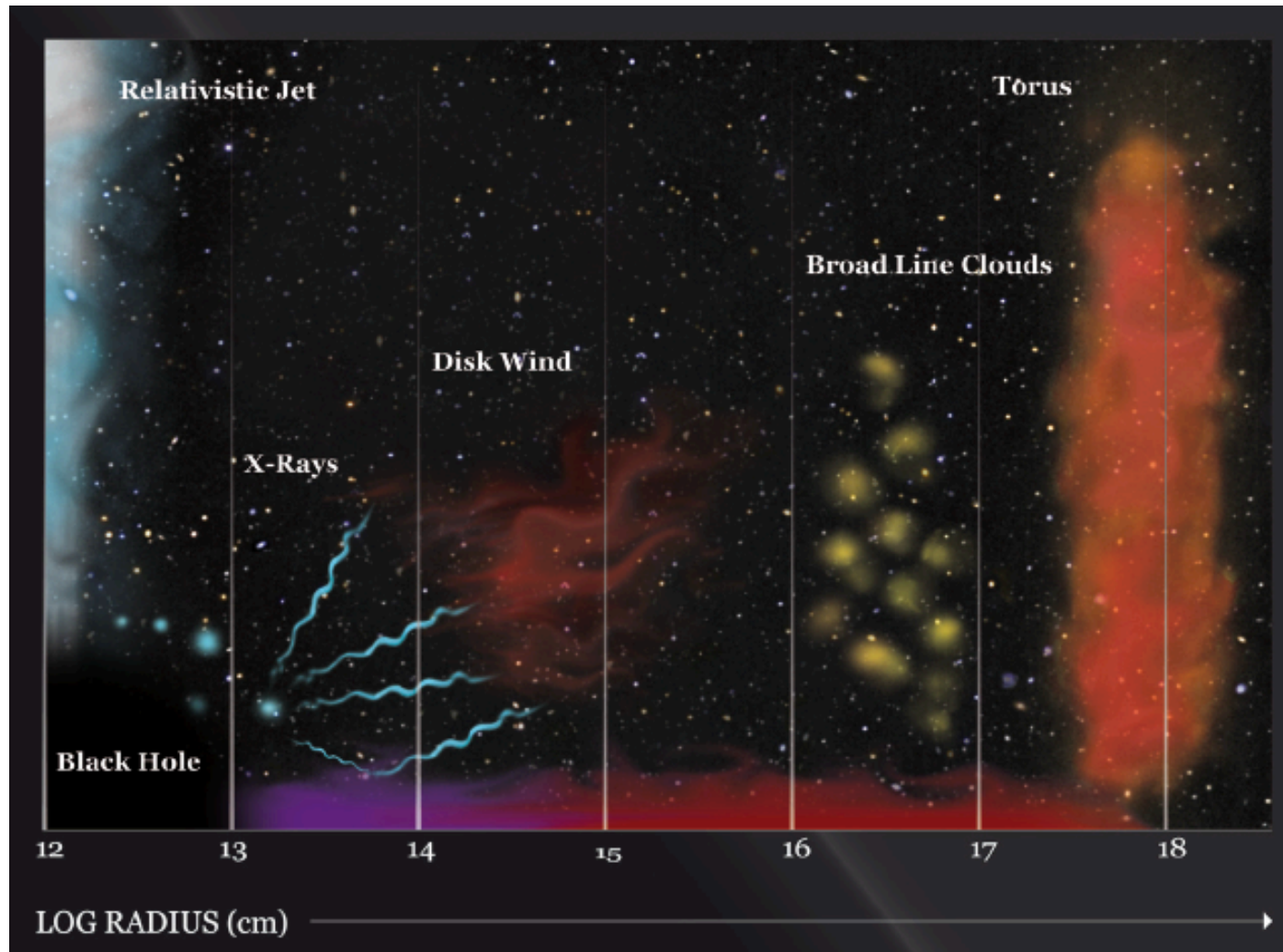


SKA will also pinpoint
growing SMBH

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IXO in the big picture

Why using X-rays to see growing SMBH?



Only moderately biased against obscuration

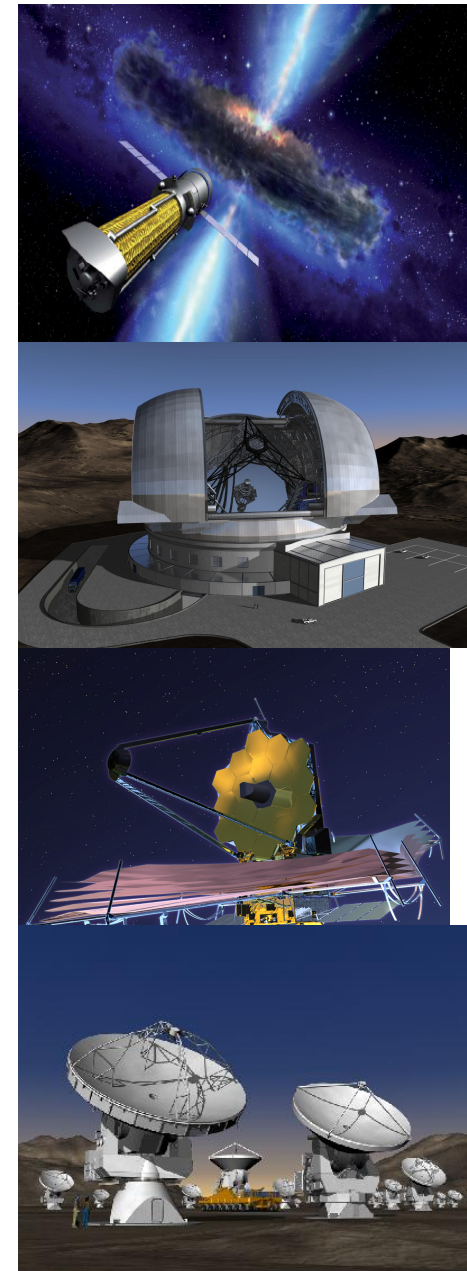
Originate from very close to the SMBH

Largely uncontaminated by host galaxy

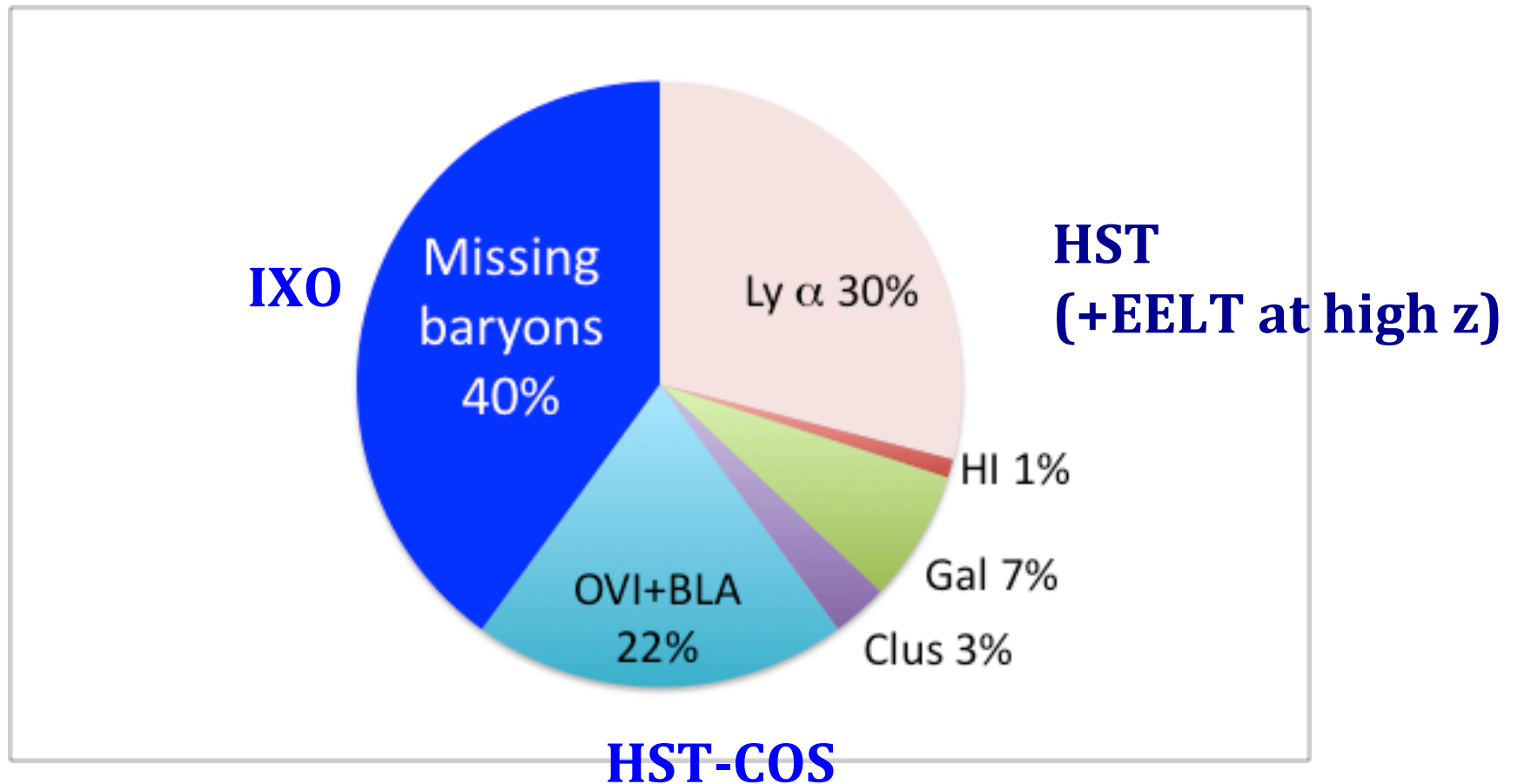
Obtaining redshifts:

1. $F_X > 5 \times 10^{-15}$ cgs, autonomous z from IXO
2. E-ELT MOS spectroscopy down to $J_{AB} \sim 26.5$ (almost unique counterparts)
3. JWST/NIRSPEC spectroscopy of fainter objects
4. ALMA CO or [CII] spectroscopy of particularly difficult targets

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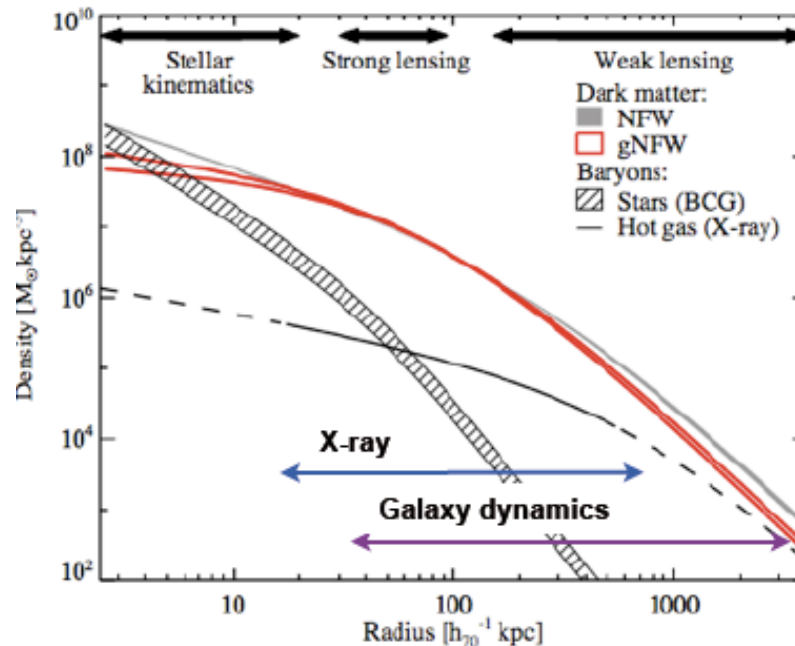


The baryon budget



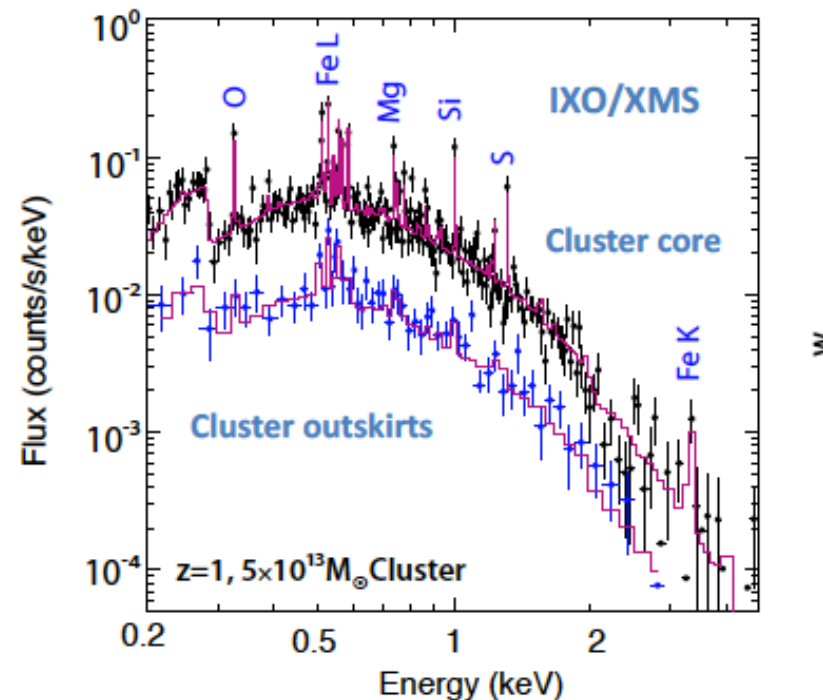
Large Scale Structure: DM and baryons in clusters

- Mass measurements from lensing (EELT, LSST) & ICM (IXO)
 - * Measure/constrain turbulence (IXO)
- Accurate measurement of baryon mass contribution to cluster mass



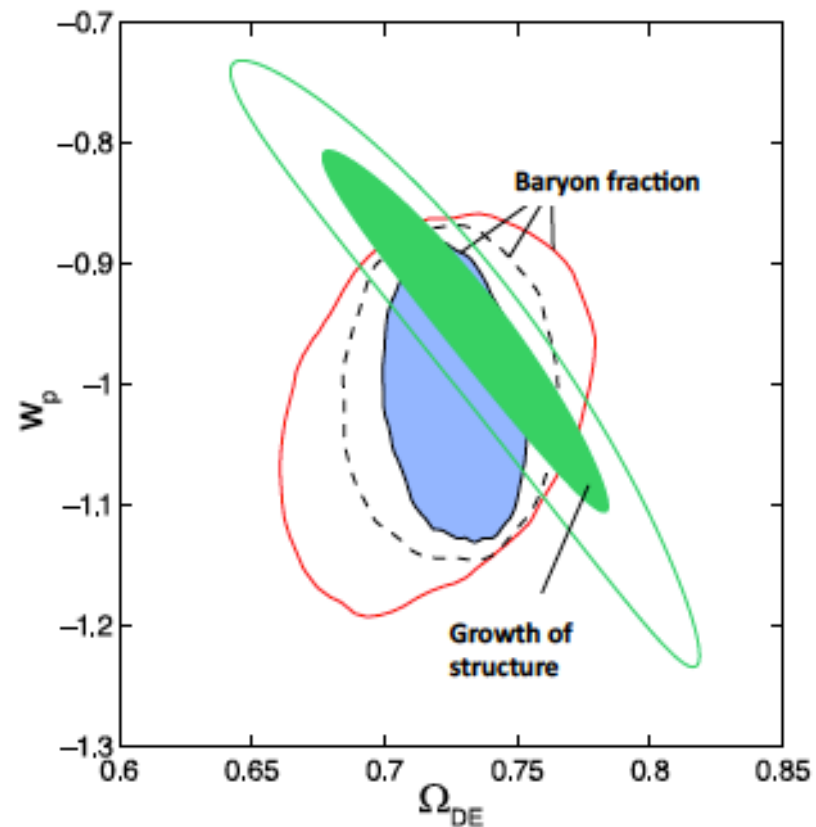
Chemical evolution

- Intracuster medium enriched to $Z \sim 0.3 Z_{\odot}$ by $z \sim 1.4$
- Study:
 - * ICM metallicities at highest z (IXO)
 - * Metallicities of individual cluster galaxies (EELT)



Precision cosmology

- DES/LSST/JPAS
 - * BAOs , SNe,
- EUCLID:
 - * BAOs & lensing
- EELT
 - * Real time expansion
- IXO/eROSITA
 - * Cluster GOS & fgas



Life cycles of matter & energy

Cold Universe:

SPICA (FIR)

ALMA (mm/
submm)

- Supernovae and SNRs
- Particle acceleration
- Stellar mass loss
- Young Stellar Objects
- Our Galaxy's ISM

Hot Universe:

IXO (X-rays)

CTA (VHE γ -
rays)

Outlook

- IXO science case contains goals which are key elements of mainstream astrophysics.
 - * Likely first opportunity for a major X-ray observatory mission to “catch up”
 - * A number of these goals drive IXO’s requirements
- Significant synergies (i.e. potential mutual benefit) with other projects:
 - * SPICA, EELT, JWST and ALMA in the top list
 - * Also EUCLID and LSST
 - * Relevant to all themes of IXO science